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56 मिमी. और उससे अधिक उँचाई की शाफ्ट के साथ धूर्णी विद्युत मशीनों का यांत्रिक कंपन — कंपन तीव्रता का मापन, मूल्यांकन और सीमा

(*पहला पुनरीक्षण*)

Indian Standard

MECHANICAL VIBRATION OF ROTATING ELECTRICAL MACHINES WITH SHAFT HEIGHTS 56 mm AND HIGHER — MEASUREMENT, EVALUATION AND LIMITS OF VIBRATION SEVERITY

(*First Revision*)

ICS 17.160; 29.160.01

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NEW DELHI 110002

July 2008 **Price Group 4**

Rotating Machinery Sectional Committee, ETD 15

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

This standard specifies the test and measurement conditions of and fixes the limits for the level of vibration severity of an electrical machine when measurements are made on the machine alone at a testing department under properly controlled conditions.

The evaluation of vibration is recognized as quite complex, as the vibration in any system is a combination of many factors and often it is difficult to analyze and assess the contribution of individual elements. The vibration limits specified in this standard are such that they do not provide undue hardships on economic production of rotating machines but at the same time are restrictive enough to eliminate faulty machines.

This standard was first published in 1987. The first revision was carried out to remove difficulties faced during the implementation of this standard and also to take into account the latest developments in the field of electro technology.

With the increasing demand for electrical machines having better performance, it has become imperative, among other things, to lay emphasis on machines with minimum possible vibrations during running.

Measurement and evaluation of vibration of rotating electrical machines were originally covered in IS 4729 : 1968 The method and data contained in this standard were based on indigenous sources. The present standard has been formulated to include a method of evaluation of vibration of rotating machines which is more internationally acceptable, namely, measurements of vibration in Vrms mode.

The vibration velocity mode used as the criteria for measurement of vibration severity is based on experience and other theoretical considerations. However, for those who have test facility for measuring displacement amplitude of vibration only, this standard recognizes this quantity for the measurement of vibration also. For this purpose, reference is drawn to **3.1**, **4.2**, **5** and **7.2.1**.

The requirements for instruments for measuring vibration severity are covered in IS 11726 : 1985 'Specification for mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity' which may also be referred.

In addition to the mode of measurement, other significant changes made in this standard are as follows:

a) This standard is applicable to dc and three-phase or single-phase ac machines having rated power up to 50 MW only.
b) The coupled machines are out of scope of this standard but efforts will be made to formulate a separate Indian Standard to cover such machines.
c) Classification of the class of vibration has been modified as N, R and S from the present normal and precision A, B and C class.
d) Range of speeds is changed for the values of vibration in mm/s.

NOTE — The mechanical vibration in large size rotating electrical machines of low speed will be covered in a separate Indian Standard.

While formulating this standard, assistance has been derived from IEC 60034-14 (1982) incorporates Amendment No. 1 (May 1991) 'Rotating electrical machines — Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher–Measurement, evaluation and limits of the vibration severity' issued by the International Electrotechnical Commission.

For run-out of maximum shaft vibration, ISO/DIS 7919-1 : 1996 'Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines' is necessary adjuncts to this standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2:1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

MECHANICAL VIBRATION OF ROTATING ELECTRICAL MACHINES WITH SHAFT HEIGHTS 56 mm AND HIGHER — MEASUREMENT, EVALUATION AND LIMITS OF VIBRATION SEVERITY

(First Revision)

1 SCOPE

1.1 This standard specifies test and measurement conditions and fixes the limits for the level of vibration severity of an electrical machine when measurements are made on the machine alone, at a testing department under properly controlled conditions.

1.2 This standard is applicable to dc machines and three-phase or single-phase ac machines with shaft centre height 56 mm and higher and a rated power up to 50 MW, at nominal speeds from 500 rpm up to and including 3 000 rpm.

NOTE — The mechanical vibrations in rotating machines of speed lower than 500 rpm shall be subject to agreement between the purchaser and the manufacturer.

1.3 For vertical and flange mounted machines vibrations are to be measured in a state of free suspension. However for vertical machines having shaft height greater than 400 mm the vibration may also be measured with rigid mounting. Under this condition the vibration limits as applicable to horizontal machines will be applicable (*see* **8.2**).

1.4 This standard is not applicable to machines mounted *in-situ*, three-phase commutator motors, single phase machines, three-phase machines operated on single-phase systems, vertical water power generators, permanent magnet generators or series wound dc machines and motors for submersible pumps.

NOTE — The shaft height of a machine without feet, or a machine with raised feet, or any vertical machines, is to be taken as the shaft height of a machines in the same basic frame, but of the horizontal shaft mounted type IMB3 (*see* IS 2253: 1974 Designation for types of construction and mounting arrangement of rotating electrical machines).

1.5 Introduction

Vibration in rotating electrical machines are caused by:

a) Unbalance in the rotating masses;
b) Slight deformations in the frame or bed of the machine caused by certain magnetic attraction between the stator and rotor;
c) Rolling bearing; and
d) Aerodynamic loads and some secondary effects such as instability of the shaft in the bearings, passive resistance, asymmetric expansion, etc.

Inspite of accurate balancing that can be achieved, residual unbalance generally proves to be the main cause of once per revolution vibrations found in the machine.

The measurement of vibrations is closely linked with the mounting of the machine and it is generally desirable to carry out vibration measurements under actual installation and operating conditions. However, to estimate the quality of balance as far as balance and vibrations of rotating electrical machines are concerned, it is necessary to measure the vibrations on the machine alone under proper test conditions which permit reproducible tests to be carried out and provide comparable measurements.

2 REFERENCES

The following standards are necessary adjuncts to this standard:

IS No.	*Title*
2253 : 1974	Designation for types of construction and mounting arrangement of rotating electrical machines (*first revision*)
4722 : 2001	Rotating electrical machines — Specification (*second revision*)
11726 : 1985	Requirements for instruments for measuring vibration severity of rotating and reciprocating machines

3 TERM AND DEFINITION

3.1 Vibrations Severity — Vibration severity is defined as a comprehensive and simple characteristic unit for describing the vibratory state of a machine, is used as the basis of classification and on the basis of theoretical considerations and practical experience. The root-mean square value of vibration velocity has been chosen as the unit of measurement for indicating vibration severity.

3.1.1 In critical cases and under special conditions, evaluation of the behaviour of a machine based on vibration severity should not be used in lieu of more precisely measured significant parameters, for example, stresses measured at bearings and joints. In general, the use of vibration severity as a criterion provides a relatively reliable evaluation requiring only simple measurements.

NOTE — 'Vibration severity' is a generic term which designate a value, such as maximum average or other significant numerical value descriptive of a vibration. The vibration severity of machine is defined as the maximum of root-mean-square value of a vibration velocity measured at significant points of a machine, such as bearings, mounting point, etc.

4 MEASUREMENT QUANTITY

4.1 General

Measurement quantities are the vibration velocity at the machine bearings and the relative shaft vibration within or near to the bearings.

4.2 Vibration Severity

The criterion adopted for vibration severity is the rms value of vibration velocity in mm/s. The greatest value determined at the prescribed measuring points characterises the vibration severity of the machine.

Alternatively, the measurement of vibration severity in displacement amplitude mode (peak-to-peak) may be carried out when facility for measurement in velocity mode is not available, if agreed between the manufacturer and the purchaser. The unit of vibration severity in displacement mode shall be microns.

4.3 Relative Shaft Vibration

The criterion adopted for the relative shaft vibration shall be in displacement mode (peak-to-peak) in the direction of measurement.

NOTE — Measurement of relative shaft vibration shall be strictly the subject of agreement between the manufacturer and the purchaser and shall not be mandatory.

5 INSTRUMENTS FOR MEASURING VIBRATION SEVERITY

The vibration measuring equipment shall be in accordance with IS 11726.

6 MACHINE MOUNTING

The vibration of an electrical machine is closely linked with the mounting of the machine. To permit evaluation as far as balance and vibration of electrical machine are concerned, it is necessary to measure the vibration on the machine alone, under properly determined test conditions, to enable reproducible tests to be carried out and to provide comparable measurements.

6.1 Free Suspension

6.1.1 The condition of free suspension may be achieved by following methods:

a) Free suspension by resilient means, such as hemp, rope wire rope, V-belt or spring;
b) Freely supported on an elastic material or spring; or
c) Freely placed on test-bed.

6.1.2 The natural oscillation frequency of the suspension system and machine, in the six possible degrees of freedom, shall be less than 1/3 of the frequency corresponding to the speed of the machine under test, as defined in **7.3**.

6.1.3 The necessary elasticity of the suspension system, as a function of nominal speed, can be determined from Fig. 1.

NOTES

1 To reduce the influence of the mass and the moments of inertia of the suspension system on the vibration level the effective mass of the elastic support should not be greater than 1/10 of that of the machine.

2 The effective mass of the elastic support shall not be greater than 10 percent of that of the motor, to reduce the influence of the mass and moment of inertia of these parts on the vibration level.

6.2 Rigid Mounting

For machine having shaft height greater than 400 mm, measurement of vibration may be carried out with rigid mounting. The machine shall be clamped firmly to a solid floor. The maximum vibration velocity measured in the horizontal and vertical directions at the machine feet (or at the base frame near to the bearing pedestals or stator feet) shall not exceed 25 percent of the maximum velocity which is measured at the adjacent bearing in either the horizontal or vertical direction.

NOTES

1 This requirement ensures that the horizontal and vertical natural frequencies of the complete test arrangement do not coincide within

a) ± 10 percent of the rotational frequency of the machine;
b) ± 5 percent of two times rotational frequency; and
c) ± 5 percent of one and two times electrical line frequency.

2 The ratio of 25 percent of foot to bearing vibration velocities is valid for once per revolution vibration and the vibration at twice the line frequency (if the later is being evaluated).

6.3 Active Environment Determination

The support system described in **6.1** and **6.2** are considered passive, admitting significant external disturbances to the machine. If the vibration with the machine stationary exceeds 25 percent of the value when the machine is running, then an active environment is said to exist and this standard does not apply.

7 CONDITIONS OF MEASUREMENT

7.1 Key

Unless otherwise specified and agreed upon, the measurement of vibration shall be carried out with half key in its shaft extension keyway.

NOTE — A full length rectangular key of half height or a half length key of full height (which should be centered axially in keyway) is acceptable as practical alternatives.

7.2 Measurement Points

7.2.1 *Measurement Points of Vibration Severity*

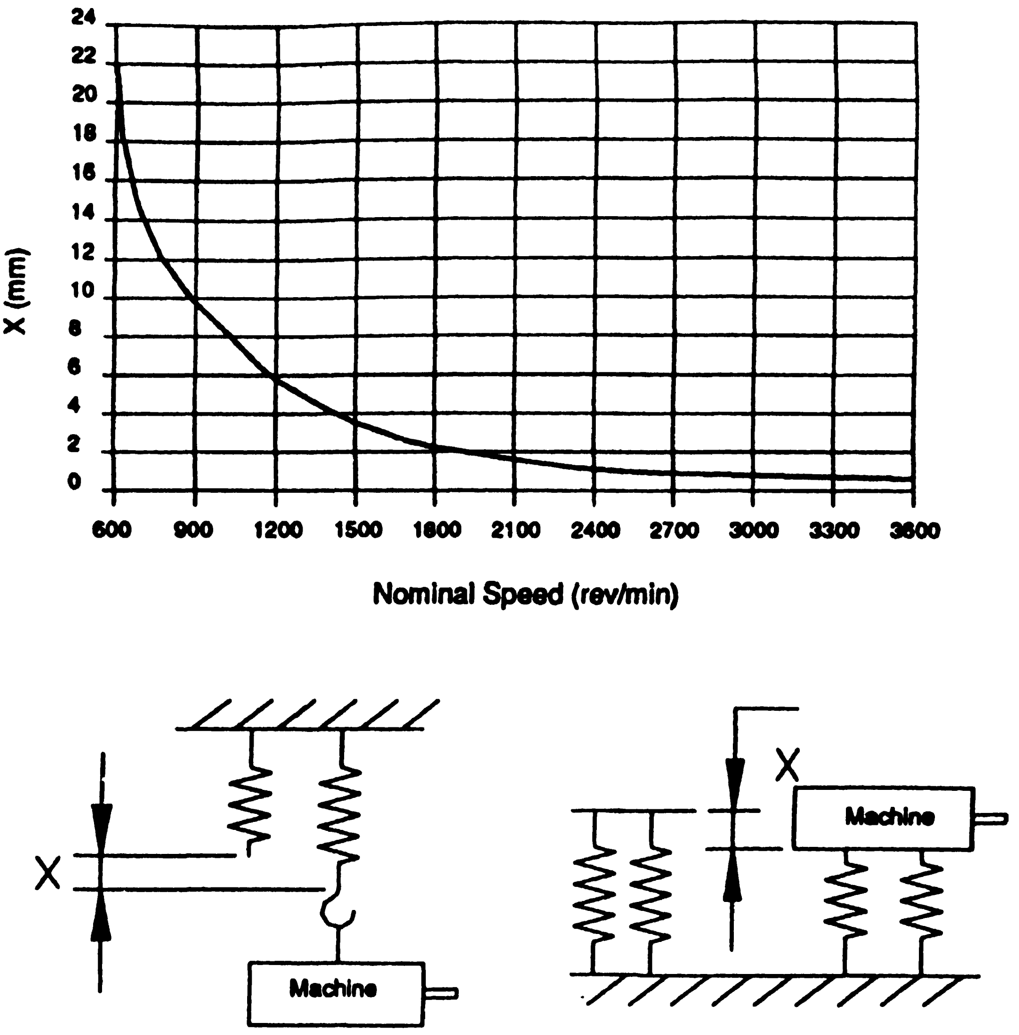
The location of the measurement points and direction to which the levels of vibration severity apply are shown in Fig. 2 for machines with end-shield bearings and in Fig. 4 for machines with pedestal mounted bearings. Figure 3 applies to those machines where measurement positions according to Fig. 2 are not possible without disassembly of parts.

NOTE — Unless otherwise stated, the measured vibration values are taken normal to the machine surface.

7.2.2 *Measurement Points for Relative Shaft Vibration Measurement*

Non-contact transducers shall be installed inside the bearings, measuring directly the relative shaft displacement or (when inside mounting is not possible) adjacent to the bearing shell. The preferred radial positions are as indicated in Fig. 5 and Fig. 6.

NOTE — In cases when shaft is not equipped with measurement transducers, a shaft stick shall be used to measure shaft motion. In this method an analyzer, accelerometer and a shaft stick are required. Shaft stick is made of hard plywood, about 450 mm long, 6 mm thick and shaped like tail at the end with a width of about 100 mm. A threaded screw is provided on stick for screwing onto the accelerometer.



Spring Suspension

Mounting on an elastic support

NOTE — To reduce the influence of the mass and the moment of inertia of the suspension system on the vibration level the effective mass of the elastic support should not be greater than 1/10 of that of the machine.

FIG. 1 MINIMUM ELASTIC DISPLACEMENT AS A FUNCTION OF NOMINAL SPEED

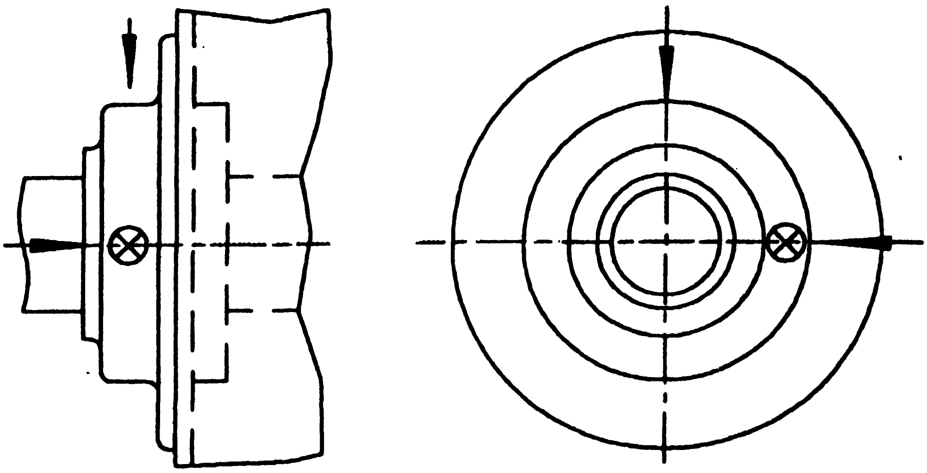


FIG. 2 PREFERRED POINTS OF MEASUREMENT APPLICABLE TO ONE OR BOTH ENDS OF THE MACHINE

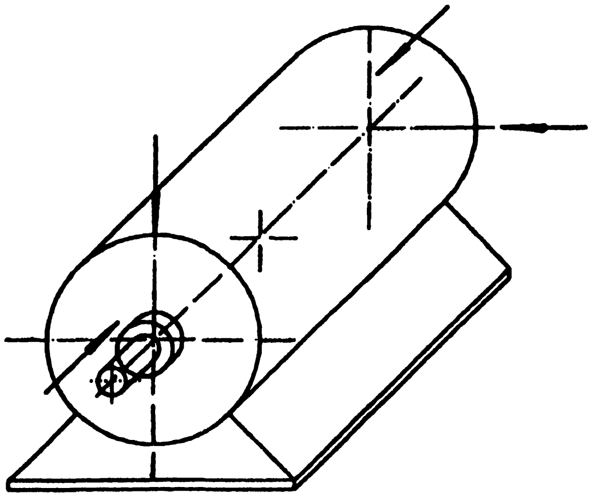


FIG. 3 MEASUREMENT POINTS FOR THOSE ENDS OF MACHINES WHERE MEASUREMENTS ACCORDING TO FIG. 2 ARE NOT POSSIBLE WITHOUT DISASSEMBLY OF PARTS

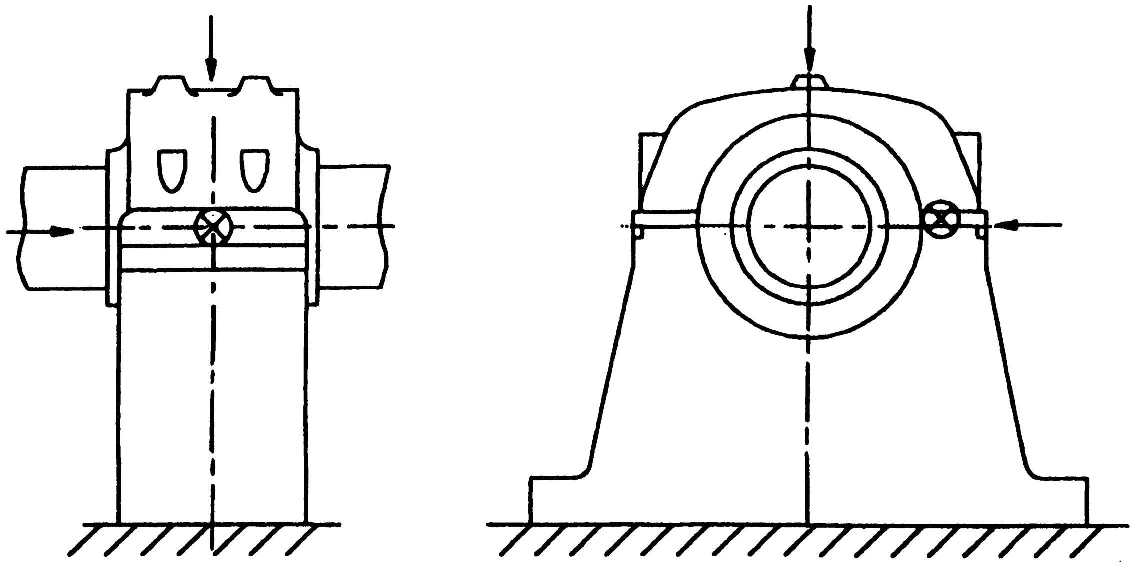


FIG. 4 MEASUREMENT POINTS FOR PEDESTAL BEARING

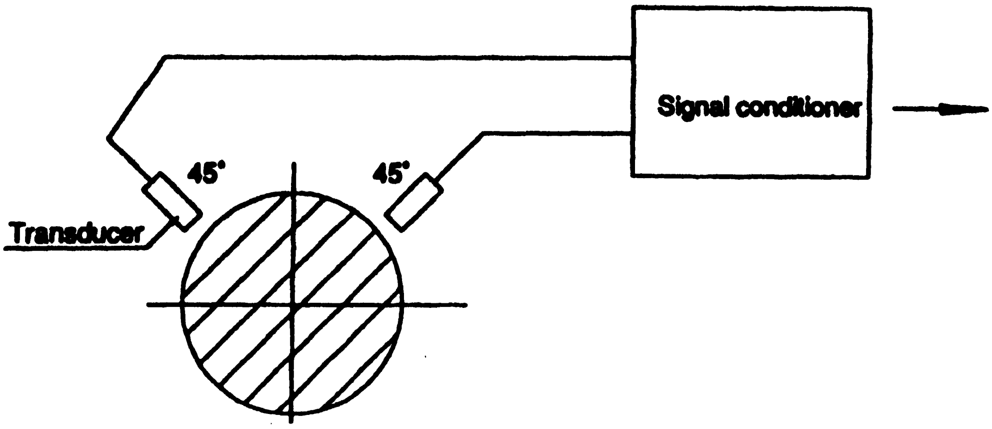


FIG. 5 PREFERRED CIRCUMFERENTIAL POSITION OF TRANSDUCERS FOR THE MEASUREMENT OF RELATIVE SHAFT DISPLACEMENT

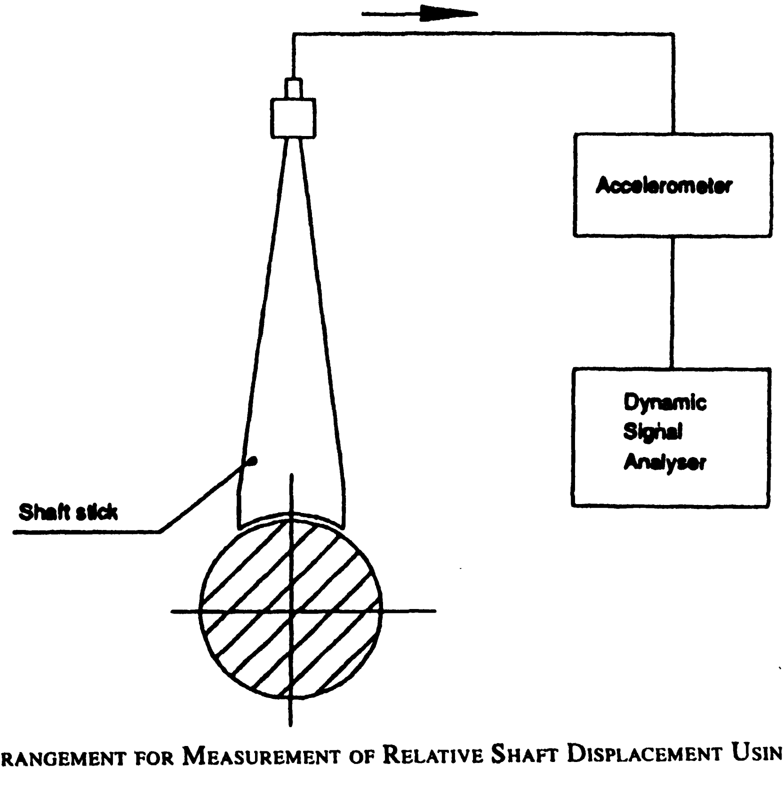


FIG. 6 ARRANGEMENT FOR MEASUREMENT OF RELATIVE SHAFT DISPLACEMENT USING SHAFT STICK

The shaft stick is attached to the accelerometer which is connected to the dynamic signal analyzer. A clean spot on the shaft is located where the shaft runout is known to be controlled to under 12.5 micron with the motor running, stick is manually pressed on to the shaft at the clean spot in the desired direction. The force is adjusted such as to only maintain a stick-to-shaft stable contact.

It should be understood that shaft stick measures shaft absolute motion rather than shaft relative motion with respect to bearing housing as in the case with the contactless shaft probes.

7.3 Operating Conditions

7.3.1 ac machines shall be fed with rated voltage and rated frequency supply having a virtually sinusoidal waveform according to IS 4722.

7.3.2 dc machines shall be excited with nominal current and shall be fed with a such voltage so as to run at nominal speed.

7.3.3 For machines with several speeds or variable speed, the test shall be carried out at lowest, middle and maximum of operational speed range. This test may be carried out using a converter supply or with sinusoidal ac supply as agreed between the manufacturer and the purchaser.

7.3.4 For machines which are bi-directional, the vibration limits apply for both directions.

7.3.5 Unless otherwise specified, measurement of the vibration severity shall be carried out under no-load and uncoupled operation at the temperature reached by the machine after a sufficient period of no-load operation.

7.4 Vibration Transducer

The mounting of the transducer used for vibration velocity measurement and the machine surface shall be as specified by the manufacturer of the transducer and shall not disturb the vibratory condition of the machine under test.

NOTE — For this it is necessary that the total coupled mass of the transducer assembly is less than 2 percent of the mass of the machine.

8 LIMITS OF VIBRATION SEVERITY

8.1 Limits on Vibration Severity in Free Suspension Condition

8.1.1 *Velocity Mode*

The limits of vibration severity, expressed in millimetres per second, for the various standard shaft heights and for three quality grades, which are called 'N'(normal), 'R' (reduced) and 'S' (special), shall be in accordance with Table 1.

NOTES

1 Provided that no other agreements are made, the recommended limits of quality grade 'N' apply to normal electrical machines. Grade 'R' machines are generally used for machine tool drives. Grades 'S' machines are used as special machines with extreme vibration requirements. Grade 'S' is applicable only to machines with shaft height ≤ 400mm.

2 For machines with shaft height (H) > 400 mm, both methods of mounting are applicable. Unless otherwise agreed, the choice of method shall be made by manufacturer.

3 The manufacturer and purchaser shall take into account that measured values can have a deviation of ± 10 percent from the true value.

4 A machine which is well balanced in itself and is of a grade conforming with the table, may exhibit large vibrations in normal service arising from various causes such as unsuitable foundations, reaction of the driven machine etc. Vibration may also be caused by driving elements with a natural oscillation frequency very close to the excitation due to the small residual unbalance of the rotating masses of the machine. In such cases, checking should be carried out not only on the machine, but also on each element of the installation.

5 Values of vibration severity, finer than Grade 'S' shall be subject to agreement between the purchaser and the manufacturer.

6 The shaft height of a machine without feet, or a machine with raised feet, or any vertical machine is to be taken as the shaft height of a machine in the same basic frame, but of the horizontal shaft foot-mounted type.

8.1.2 *Displacement Amplitude Mode*

The measurement of vibration severity in displacement amplitude mode may be carried out when the facility for measurement in velocity mode is not available in the instrument. The limits of vibration in displacement amplitude mode as given in Table 2 are derived values using the following formula:

$$A = 0.45\ V_{rms}/f$$

where

A = Double amplitude of vibration displacement, mm;

V_{rms} = RMS value of velocity of vibration, in mm/s; and

f = Frequency of vibration.

This is based on the assumption of sinusoidal simple harmonic motion corresponding to rotor speed that is $f = \text{rpm}/60$

NOTE — The conversion from velocity to displacement can be accomplished for single frequency harmonic component using this formula.

8.2 Limits on Vibration Severity in Rigid Mounting Condition

For machines having shaft height greater than 400 mm, measurement of vibration may be carried out with rigid mounting. The limits of vibration severity, measured under rigid mounting condition shall be 80 percent of the value specified in Table 1 and Table 2.

8.3 Limits of Vibration Velocity with the Twice Line Frequency for ac Machines

Two pole machines may have significant vibration at twice the frequency of power system. The correct evaluation of these vibration components requires a rigid mounting of the machine which complies with the requirements given in **6.2**.

For two pole machine with shaft height H greater than 225 mm, the above evaluation shall be part of the basic machine type-test to establish the existence of significant twice line frequency vibration.

Machine having $H > 225$ mm and twice the frequency vibration, shall be tested in rigid mounting and shall not exceed the values as specified in **8.1**, corresponding $H > 400$ mm.

8.4 Axial Vibration

The evaluation of axial bearing vibration correlates with thrust pulsation which could cause damage to the metal liner of sleeve bearings or to parts of antifriction bearings. Axial vibration of these bearings shall be evaluated in the same manner as transverse vibration and limits of Table 1 and Table 2 shall apply.

Table 1 Limits of Vibration Severity in Rotating Electrical Machines Measured in a State of Free Suspension (Velocity Mode)

(*Clauses* 8.1.1, 8.2, 8.4, 8.6 *and* 8.7)

SI No.	Shaft Height mm	$56 < H \le 132$		$132 < H \le 225$		$225 < H \le 400$		$H > 400$	
(1)	(2)	(3)		(4)		(5)		(6)	
i)	Range of speed, rpm	500 to 1 500	> 1 500 and up to 3 000	500 to 1 500	> 1 500 and up to 3 000	500 to 1 500	> 1 500 and up to 3 000	500 to 1 500	> 1 500 and up to 3 000
		rms values of vibration velocity in mm/s for the shaft height *H*, in mm							
ii)	N (normal)	1.8	1.8	1.8	2.8	2.8	4.5	2.8	4.5
iii)	R (reduced)	0.71	0.71	0.71	1.12	1.8	2.8	—	—
iv)	S (special)	0.45	0.45	0.45	0.71	1.12	1.8	—	—

Table 2 Derived Values of Limits of Vibration Severity in Rotating Electrical Machines Measured in State of Free Suspension (Displacement Mode)

(*Clauses* 8.1.2, 8.2, 8.4 *and* 8.6)

Shaft Height	$56 < H \le 132$						$132 < H \le 225$						$225 < H \le 400$						$H > 400$					
(1)	(2)						(3)						(4)						(5)					
Speed, rpm	500	600	750	1 000	1 500	3 000	500	600	750	1 000	1 500	3 000	500	600	750	1 000	1 500	3 000	500	600	750	1 000	1 500	3 000
	Vibration limit in maximum displacement amplitude, in µm																							
N (normal)	96	80	64	48	32	16	96	80	64	48	32	25	150	125	100	75	50	42	150	125	100	75	50	40
R (reduced)	36	30	24	18	12	6	36	30	24	18	12	10	96	80	64	48	32	26	—	—	—	—	—	—
S (special)	24	20	16	12	8	4	24	20	16	12	8	6	50	60	40	30	20	17	—	—	—	—		—

NOTE — For the purpose of Table 2, '*f* 'is assumed as frequency corresponding to rotor rpm. But for evaluation the dominant frequency should be determined by spectrum analysis and only that frequency should be used for calculation.

8.5 Limits on Relative Shaft Vibration

Relative shaft vibration measurements are recommended only for two pole machines with sleeve bearings and rated power above 2 000 kW and shall be the subject of prior agreement between manufacturer and purchaser with respect to necessary provisions regarding the installation of shaft measurement transducers.

When machines with sleeve bearings have special provisions for the installations of shaft measurement transducers, the limits for the relative shaft vibration displacement shall be as per Table 3.

8.6 Limits of Vibration for Machines Erected at Site

The machine may exhibit greater vibration when erected at site, depending on the balance of apparatus to which the machine is coupled and on the stiffness of the foundations or supporting structures. Because of these factors higher vibration limits are permissible on site, but the values should not exceed 125 percent of the value specified in Table 1 and Table 2. The responsibility of ensuring the above lies with the user/site personnel.

8.7 In case of dispute arising out of the two methods used, the values in Table 1 shall prevail for deciding conformity to this standard.

Table 3 Limits for the Maximum Shaft Vibration (S_{p-p}) and the Maximum Run-Out

(*Clause* 8.5)

SI No.	Vibration Grade	Number of Poles	Maximum Relative Shaft Displacement µm	Maximum Run-Out µm (For Reference Only)
(1)	(2)	(3)	(4)	(5)
i)	N	2	70	18
ii)	R	2	50	12.5

NOTES

1 Machines with vibration grade R are frequently specified for high-speed drives in critical installations.

2. All limits apply to both 50 Hz and 60 Hz machines.

3 The maximum relative shaft displacement limits include the run-out. For the definition of the run-out (*see* ISO/DIS 7919-1).

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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